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THE DEVELOPMENT OF A NEW DRIFT CHAMBER WITH A NEW GAS MIXTURE

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ABSTRACT

A drift chamber of 1 cm spacing incorporating parallel foils which act as field shaping electrodes was successfully operated producing a linear space to drift time ratio that will enable the determination of positions of charged particle tracks directly from timing spectra. The results indicate that spatial resolutions of 100 - 150 microns can be obtained from a single chamber filled with an Argon-Methane-Acetylene gas mixture at atmospheric pressure. A simplified construction which eliminates field shaping wires and uniform equipotential lines in the chamber which results in uniform electron drift velocities are the main advantages of this new design.

THE DEVELOPMENT OF A PARALLEL FOIL DRIFT CHAMBER AND A NEW GAS MIXTURE

It has been reported in various papers that positions of charged particle tracks can be determined quite precisely by measuring the drift time of the primary electrons.[1-6]

A characteristic feature of the drift chambers with multi-wire structure is that the cathodes are made of parallel equi-distant wires with increasing potentials applied in order to obtain an optimal field configuration for the best spatial resolution. In this case every other wire in the signal plane is called a drift wire and is normally larger in diameter than the signal (anode) wire. In the case of parallel plane electrodes, which are kept at equal distances from the anode wire plane the optimization of the electric field is not possible, therefore the field in the drift space varies drastically.[5]

In this paper we will talk about a drift chamber with parallel thin foils positioned between the anode wires with the plane of each foil perpendicular to the anode wire plane. This test chamber was built to show that very uniform drift velocities and consequently high spatial resolutions can be obtained with a simplified construction.

CONSTRUCTION

Figure 1 shows a perspective view of the parallel foil drift chamber (PFDC) with three cells covering a 15 x 6 cm^2 active area. The insulating G-10 spacers are epoxied on a rigid G-10

main window frame. The spacers and the flat surface on which they are positioned are precision-machined to insure proper alignment of the foils. The signal wires leave the chamber via feed-through and are soldered into position with 25 grams of tension applied. The hard aluminum foils (6 mm wide) are stretched and then epoxied to the spacers. The cells are covered with kapton sheets to isolate the active area from the rest of the detector enclosure. A high voltage of -2600 volts was applied to the aluminum foils with the signal wires at ground, and the pulse signal was amplified by a gain of 100 with a commercial unit.

The drift time is measured with a time to amplitude converter (TAC) and stored in a multichannel analyzer (see Figure 2). A coincidence pulse obtained from the plastic scintillators which cover the entire sensitive area of the PFDC starts the TAC and the pulse from the PFDC stops it. The discriminator level was kept at 50 mv, thus accepting the pulses above 0.5 mv. The average pulse rise time was measured to be 5 nsec for a minimum pulse height of 4 mv with a majority of the pulses saturating the amplifier. Consequently, time slewing due to the fixed threshold discriminator was minimal (less than 2 nsec).

FIELD PLOT

Equipotential lines in a cell of the PFDC were determined on a resistive paper (Teledeltos paper). Figure 3 shows very uniformly spaced equipotential lines and the electric field lines (dashed) in a half cell. The field does not increase rapidly until very near the anode wire as we see in Figure 4. A considerable overall improvement in the uniformity of the

field can be observed with this plot compared to fields obtained with a field shaping wire network.[3,6]

DATA

Tests were carried out using cosmic rays. The random distribution of cosmic rays in space simplifies arrangements for testing a single drift chamber. Achieving a uniform distribution of the number of events for equal time intervals in the drift time spectrum indicates that the drift velocity of electrons across the drift space is constant. When this is achieved the position of a track can be read directly from from the drift-time spectrum.

Results show that the electron drift velocities decrease in the high field region of the anode wire when CH_4 gas is added to Argon, and the velocities are even slower in the low-field drift region (see Figure 5). Our earlier research shows that adding C_2H_2 to Argon has the opposite effect on the electron drift velocities in the high field region. The correct combination of the three gases (70% Argon, 22% C_2H_2, and 8% CH_4) produces the desired results as shown in Figure 6.

The Figures 5 and 6 contain a photograph of the spectrum taken from the multichannel analyzer for each gas mixture showing the number of events as a function of drift time. The space coordinates x_j of the distribution are related to the drift time t_i by:

$$x_j = a \sum_{i=1}^{j} f(t_i) \Big/ \sum_{i=1}^{N} f(t_i)$$

where a = 1 cm is the total drift distance corresponding to the total drift time produced by N channels in the time spectrum $f(t_i)$.

The charged particle detection efficiency of the chamber, as a function of the applied high voltage together with a photograph of the positive induced pulses obtained from the high voltage foils are shown in Figure 7 when $Ar/C_2H_2/CH_4$ mixture was used. The vertical scale is 1 mv/division and the horizontal scale is 10 nsec/division.

For the next generation of PFDCs we plan to replace the aluminum foils with resistive foils to determine the position of the particle tracks normal to the electron drift coordinate simultaneously by recording the RC rise time related to the localization of the induced pulses.[7] This will eliminate multi-track ambiguities with two dimensional dependent coordinate measurements of the track positions.

CONCLUSIONS

1. The results show that spatial resolutions of 100-150 microns can be obtained from a single parallel foil drift chamber. This requires $\pm$ 2 nsec accuracy with the electronics.
2. It is necessary only to know the relative positions of the wires in the PFDC to obtain high accuracy in locating the particle tracks. This can be easily accomplished since the windows are transparent, and there are no obstructions (foils, wire planes, etc.) in the direction of the particle beam. The same resolution can be obtained with PFDCs with a much larger active area.
3. The multiple Coulomb scattering of charged particles is minimal with this new type of drift chamber.

ACKNOWLEDGMENTS

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FIGURE CAPTIONS

Figure 1. A perspective and a cross-sectional view of the parallel foil drift chamber (PFDC).

Figure 2. A readout logic diagram for the PFDC.

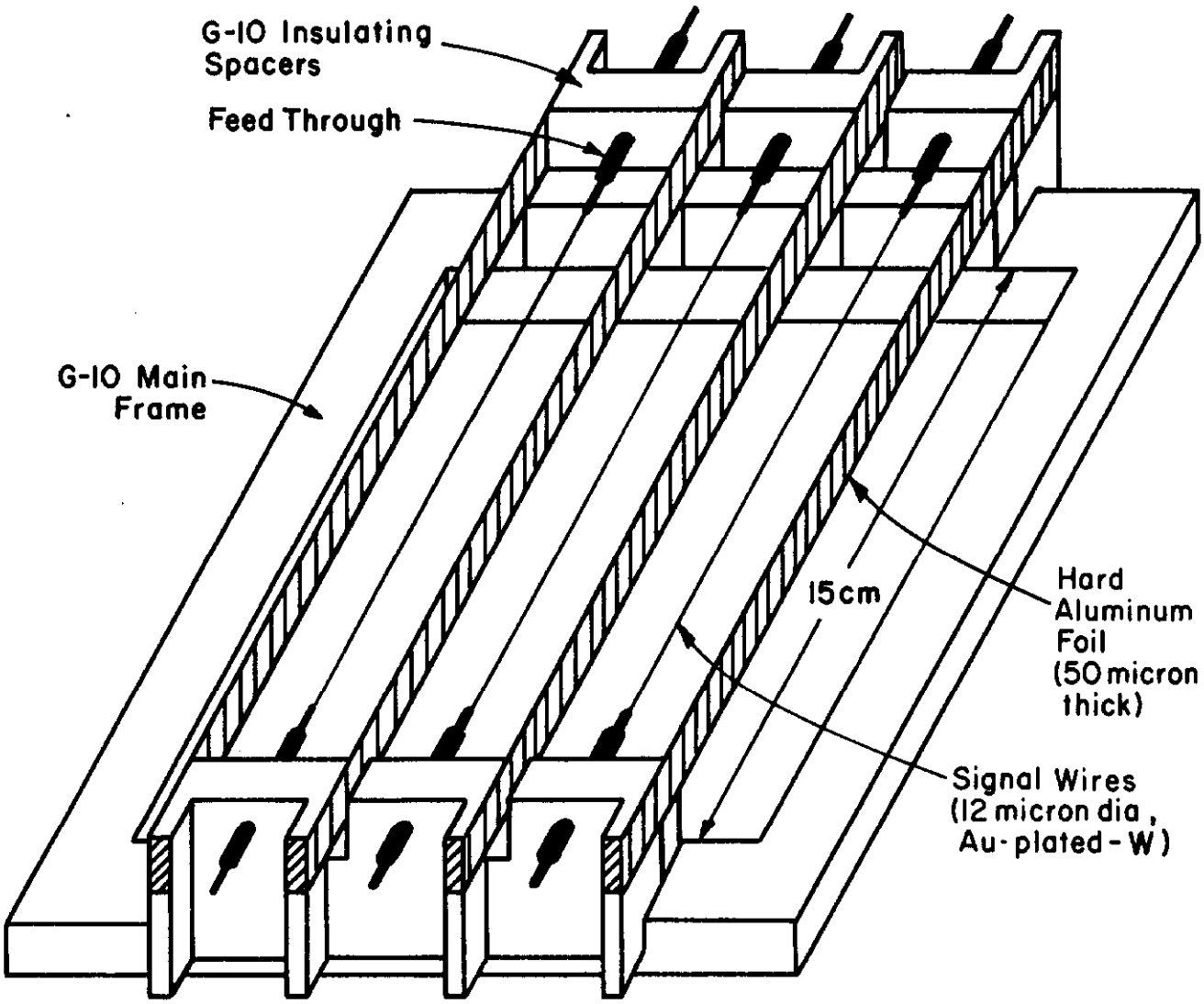
Figure 3. The uniformly spaced equipotential lines and the field lines in a half cell.

Figure 4. The electric field plot across the chamber.

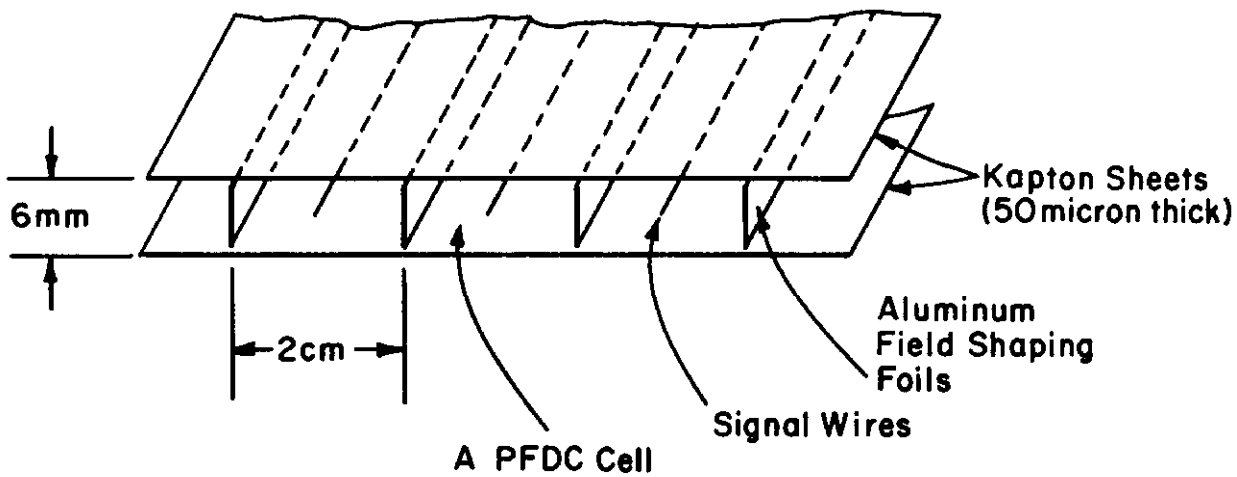
Figure 5. Drift time as a function of the drift velocity using 10% CH_4-90% Ar gas mixture. The photograph shows the number of events as a function of the drift time.

Figure 6. Drift time as a function of the drift velocity using 70%Ar - 22%C_2H_2- 8% CH_4 gas mixture. The photograph shows the number of events as a function of the drift time.

Figure 7. Detection efficiency of the chamber as a function of the applied voltage together with a photograph of the induced pulses obtained from the high voltage foils. Vertical scale: 1mv/division; Horizontal scale: 10 nsec/division.



Perspective View



Cross-Sectional View

Fig. 1

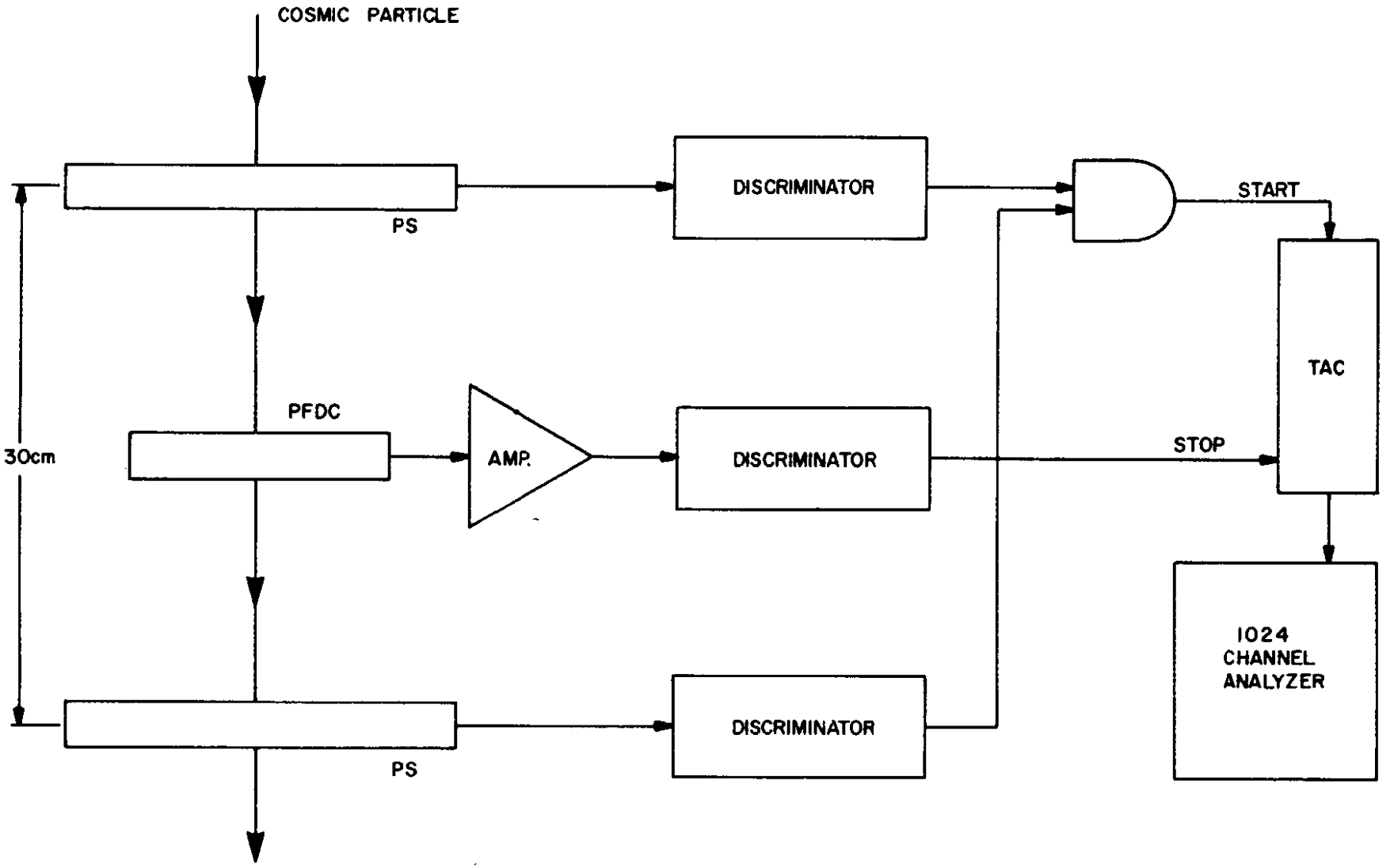

COSMIC PARTICLE
PS
DISCRIMINATOR
START
TAC
PFDC
AMP.
DISCRIMINATOR
STOP
30cm
1024
CHANNEL
ANALYZER
DISCRIMINATOR
PS

Fig. 2

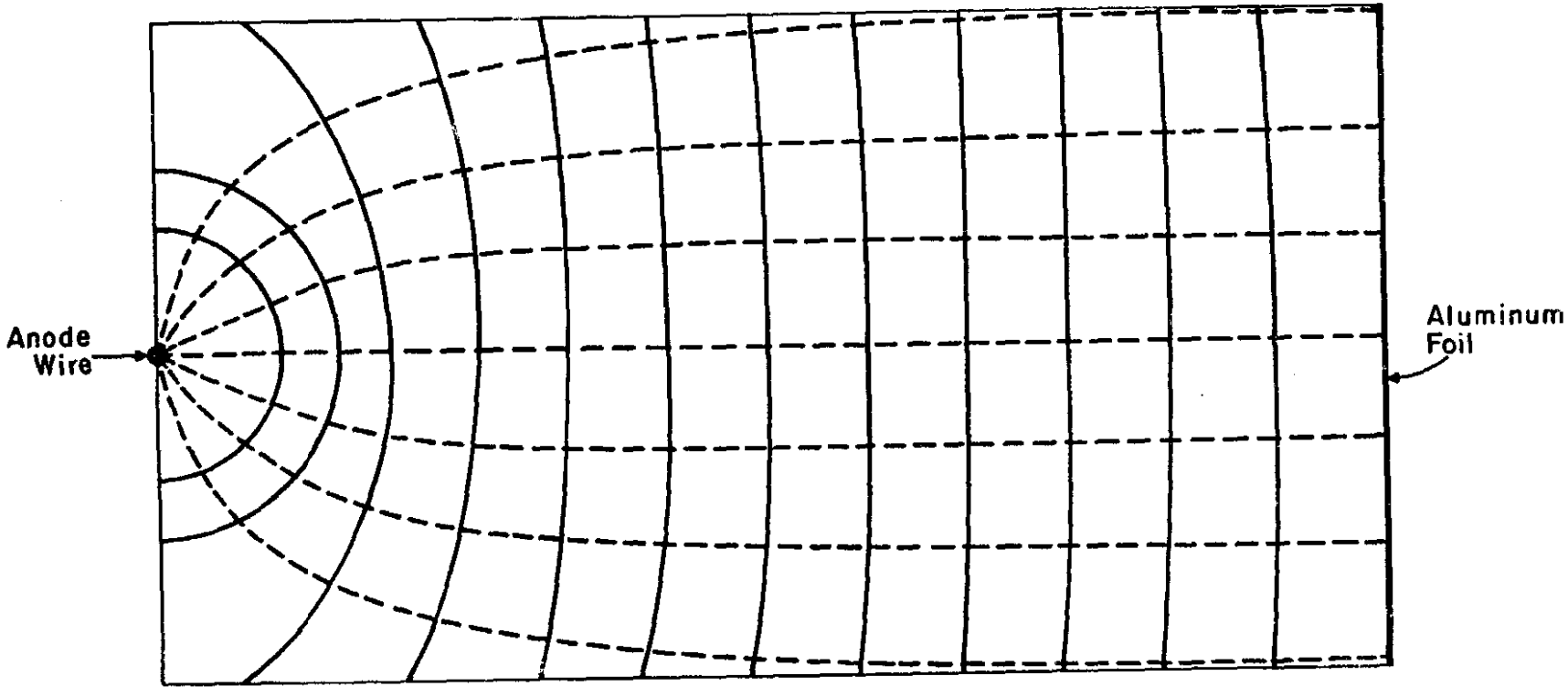


Fig. 3

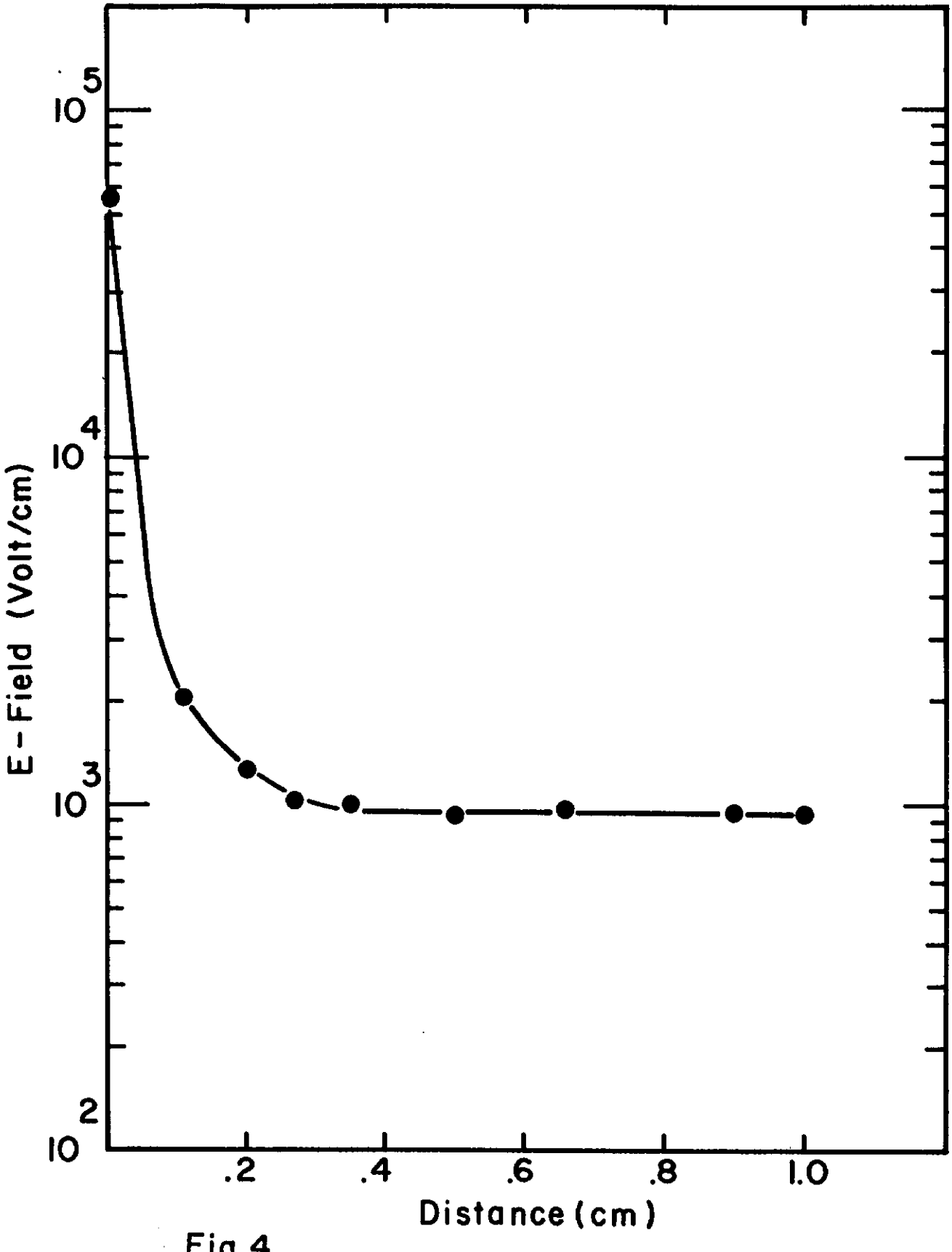


Fig.4

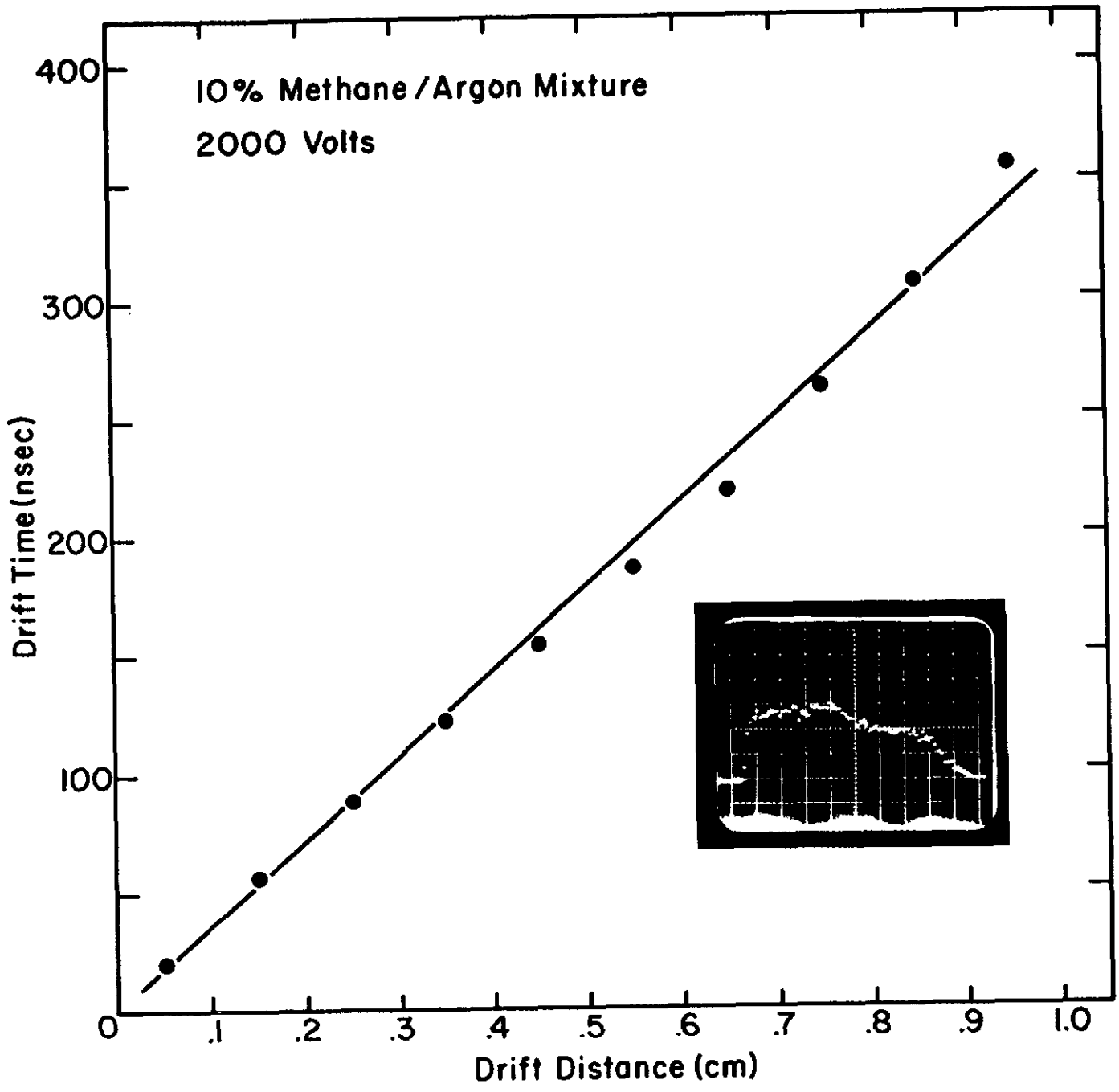

10% Methane / Argon Mixture
2000 Volts
Drift Time (nsec)
400
300
200
100
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
Drift Distance (cm)

Fig. 5

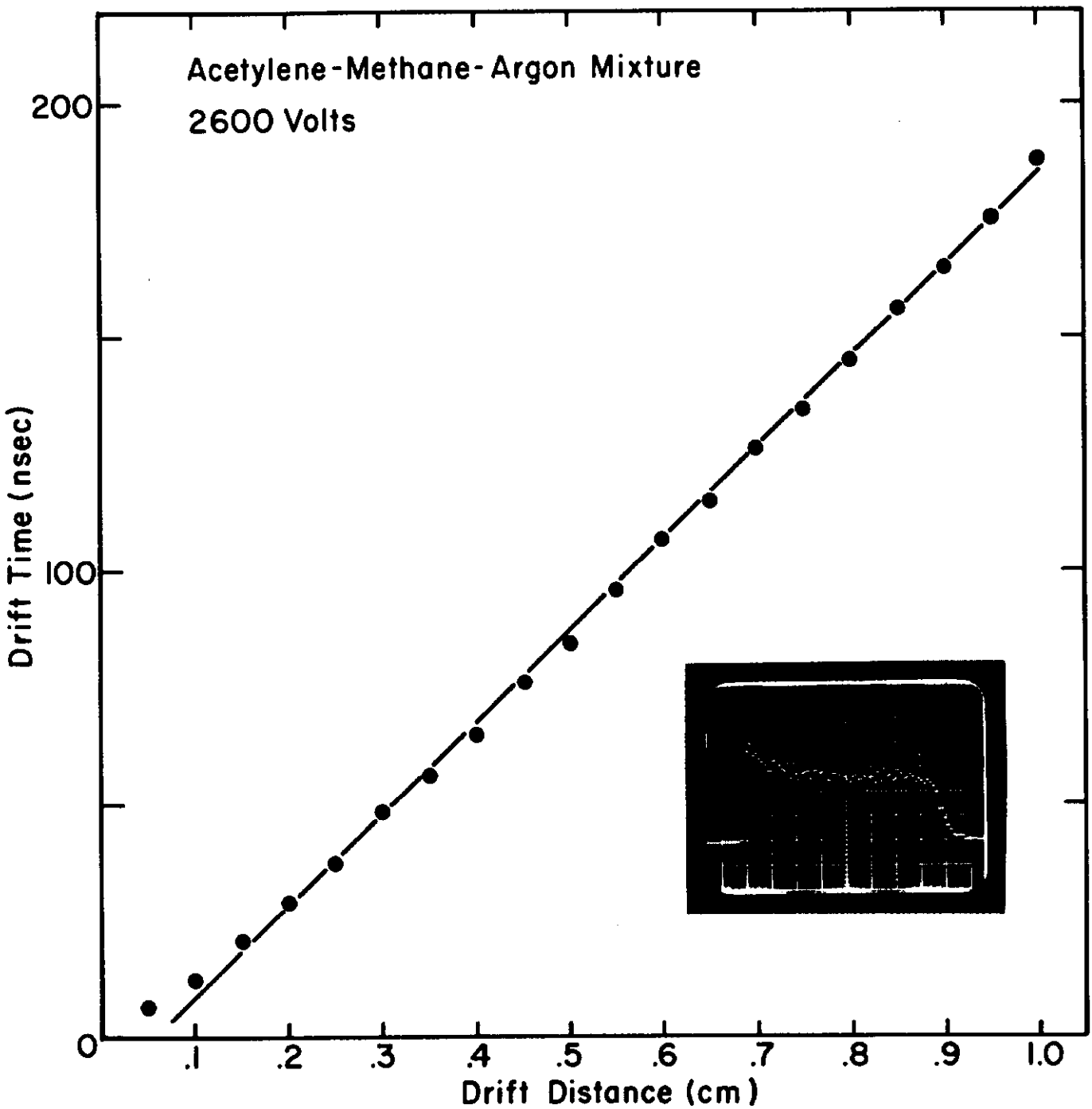

Acetylene-Methane-Argon Mixture
2600 Volts
200
100
0
Drift Time (nsec)
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
Drift Distance (cm)

Fig.6

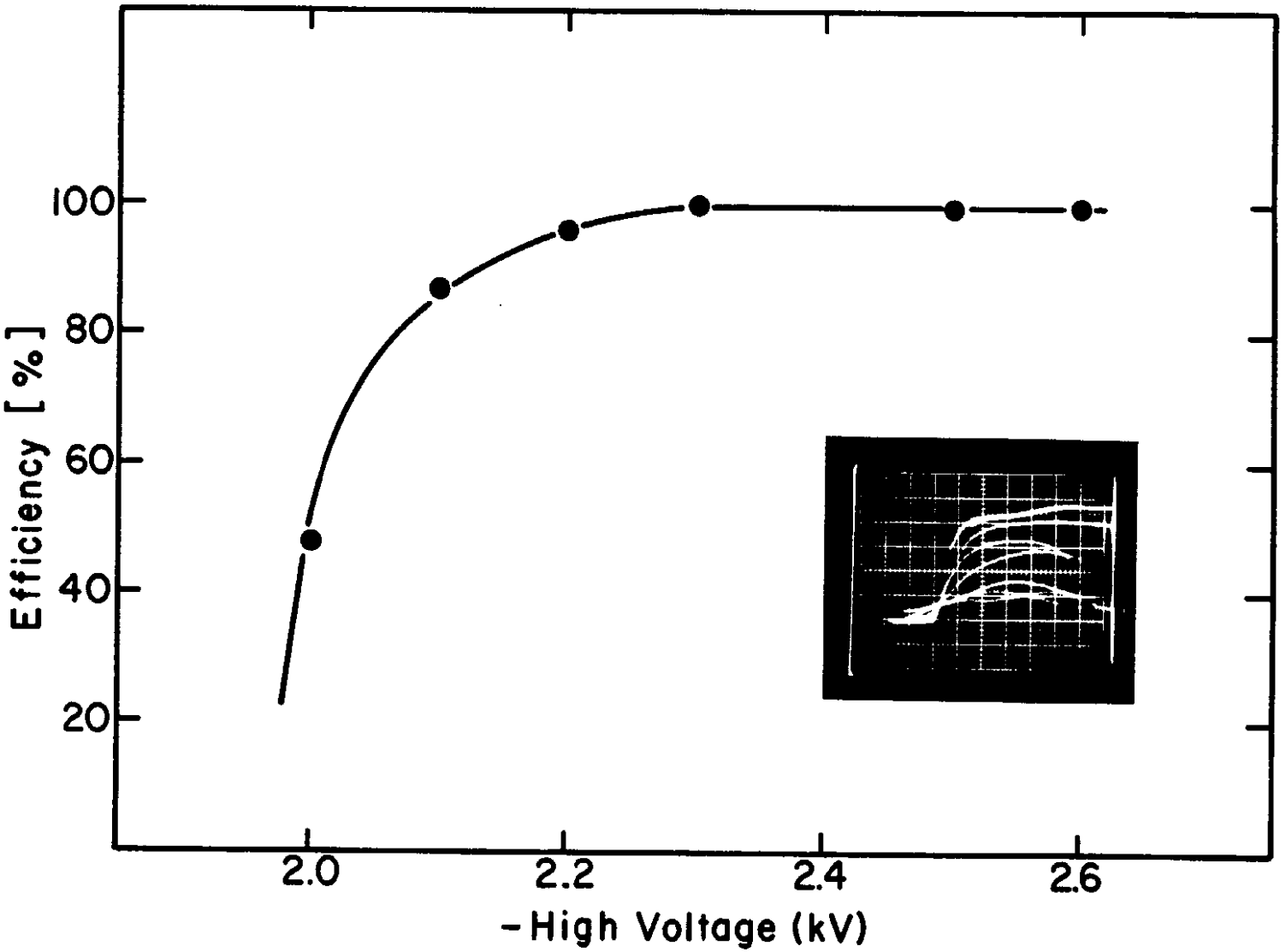


Fig. 7